SECTION V.—SEISMOLOGY.

RESUMPTION OF SEISMOLOGICAL WORK.

By C. F. MARVIN, Chief of Bureau.

[Dated, Weather Bureau, Washington, D. C., July 1, 1914.]

Authority having been granted by Congress for the Weather Bureau to conduct seismological work, to begin with July 1, 1914, this work will accordingly be resumed.

As but limited funds are available for inaugurating the work, it will consist at the beginning of a systematic collection of noninstrumental reports, to be rendered on postcards or other appropriate form, giving the essential features of such slight earthquakes as are likely to be felt in almost any part of the United States. Particular attention will be paid, however, to the Pacific coast and Rocky Mountain regions; the Mississippi Valley in the vicinity of Missouri; certain parts of New York State and New England, and possibly the region in the vicinity of Charleston, S. C.

It is believed that by the collection and study of numerous reports of this character it will be possible to locate sections of the United States where seismic motion on existing fault lines is taking place with some frequency and regularity. The location and mapping of these points of weakness are of great importance in the conduct of certain kinds of engineering work, especially those relating to great water-supply projects or similar engineering undertakings where it is necessary to provide against injuries resulting from possible earthquake motions.

The development of the work along instrumental lines, which will proceed as rapidly as funds permit, contemplates the establishment of a limited number of instrumentally-equipped stations that will serve to yield record not only of sensible seismic phenomena, but also of the great unfelt vibrations resulting from large distant earthquakes.

The seismological work will be under the supervision of Professor William J. Humphreys.

SEISMOLOGY.

By W. J. HUMPHREYS, Professor of Meteorological Physics, in charge of Seismological Investigations.

[Dated, Weather Bureau, Washington, Feb. 1, 1915.]

HISTORICAL AND INSTRUMENTAL.

Although earthquakes have so appealed to the imagination as to command a prominent place in mythology, in tradition, and on the pages of all authentic history, nevertheless the science of such phenomena instead of being old like astronomy and geometry is one of the youngest. Noninstrumental records of earthquakes have it is true, been kept in Japan and Italy for many centuries, and even ingenious devices that would indicate the occurrence of disturbances were set up in China nearly 1,800 years ago, yet modern seismology, the science of earthquakes and the interpretation of their many phenomena, is indeed so very modern as to require considerable liberality in conceding it an age of even 30 to 40 years. It began only with the use of apparatus so designed and constructed as to record the times of beginning and ending of every material tremor, even though not sensible to man, its amplitude, direction, period, and other characteristics. As these instruments have increased in number and distribution throughout the world our knowledge of the structure of the earth, both in the outer shell and in its deeper portions, has become more abundant and more specific.

The designing of apparatus that will record the onset, the period, the amplitude, and the subsidence of a vibration, often feeble beyond human sense to detect, caused by a break or a slip in the rocky crust of the earth thousands of miles away, in the very antipodes, it may be, challenges, as one may well imagine, the highest type of inventive genius, while its construction and maintenance puts to test the skill of the trained mechanician. Similarly, the interpretation of these records calls for much thought by the geophysicist and the extensive use of none too easy mathematics.

From this it might seem that seismology is an ideal subject for the private diversion of the abstract scientist, as indeed it is. Those who attempt difficult problems for the mere exhilaration they afford, or revel in the luxury of intricate equations, can find in seismology every excuse for endless self-indulgence.

APPLIED OR PRACTICAL.

"To have is to use" is an axiom that applies as well to knowledge as it does to land and chattels. Steam soon moved many things besides teakettle lids. Similarly, the knowledge, so far as that has already been gained, of where earthquakes occur, why they occur, and how the earth vibrates under their shocks, has already found eminently practical applications, and it is quite certain, from the nature of these applications, that they will keep in close touch with the growing knowledge. Thus the fact, now generally recognized, that perhaps all notable earthquakes are due to sudden breaks and displacements in the rocky crust, leads to two important deductions: (*a*) That each geologic fault, each surface across which the strata are nonconformable or displaced, presumably has been the origin, the focus, or epicenter of from one to many earthquakes; (*b*) that since, in general, a break remains forever a weak place in the earth's crust, earthquakes are most likely to recur just where they occurred before. The first of these deductions, because it concerns things that have already passed, some of them hundreds, thousands, possibly millions of years ago, can neither command the attention of the engineer nor catch the interest of the man of affairs. The second deduction, however, concerns not the past but the future and therefore has a practical value that increases directly with the frequency with which disturbances recur. Hence wherever seismic shocks are at all frequent, especially in populated portions of the world, a careful engineer would not span an active geologic fault with a bridge, aqueduct, dam, or other important structure if it could be avoided. Neither would a properly informed and prudent banker finance such an enterprise unless the success of the project could be safeguarded.

Indeed it would be well to keep these considerations clearly in mind whenever building important permanent structures even in the least disturbed regions, for it can not be said with certainty that there is any place entirely free from the earthquake's shock nor can anyone foretell when it will come or how severe it may be.

Where such disturbances are rare it often is not advisable to incur heavy expense simply to minimize the danger. But the more important the structure in question, the more vitally it affects the community; the more frequent and severe the shocks, the greater the need for precaution—the avoidance of all well-marked seismic breaks or geologic faults.

But precautions, however urgent, can not in general be taken unless the engineer is first provided with the necessary information—with detailed maps locating seismic centers. As this need applies equally to all parts of the country, it clearly is a proper function of the National Government to supply, as rapidly as practicable, maps and other information on seismic frequency and seismic severity. But how shall the Government fulfill this function? Through what agency shall it operate in constructing these maps which are so essential?

In answer to these questions it may be said that many have long recognized that of the various Federal scientific institutions the Weather Bureau is the best fitted to undertake this work, because it already has approximately 200 principal stations, widely distributed over the entire United States and manned by trained observers familiar with the maintenance of delicate automatic instruments. In addition it receives reports from over 4,000 cooperative observers. Thus it has all the necessary organization for the continuous and systematic collection of data concerning earthquake phenomena, and Congress has recently authorized it to do this work.

For the purpose of furthering this work as much as possible the bureau will assemble and publish as often as may be necessary not only its own instrumental records, but also any of reliable nature that may kindly be offered for that purpose by other institutions operating seismographs. In addition to this it is collecting and will publish noninstrumental reports of earthquakes. Question cards on which these reports may easily be rendered have already been sent to many persons throughout all the States and will be furnished to any others who are sufficiently interested to cooperate without cost to the bureau in this important work. The time required of each observer to prepare these card reports can not amount, on the average, to more than a very few minutes during the course of an entire year. In fact, during most years the majority of observers will have nothing whatever to record.

The following copy of the question card now in use may interest those who have not seen it:

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU (SEISMOLOGY).

Cross out words and parts not applicable, and fill in all remaining spaces. Use other side, if desired, for additional description and information.

Date of earthquake: ...., 19....
Time of beginning (use railroad time): Hour, ... min., ..., a. m., p. m.

Location of observer:
- On mountain, hill, plain, in valley. Outdoors, indoors, 1st, 2d, 3d, ... floor.
- State ...., town ....
- Street ...., No. ....
- If in country, distance ...., direction...... from .... (nearest P. O. or town).

What doing: Lying down, sitting, standing, walking, ...
Onset of shocks: Abrupt, rapid, gradual.
Nature of shocks: Bumping, rocking, trembling, twisting, ...
Intensity (give number, see scale on other side): ....
Number of shocks during earthquake: ....
Duration of each: ....
Direction of vibration: N.-S.; NE.-SW.; E.-W.; SE.-NW.
Sounds: No, yes. Before, with, after shocks. Faint, loud, rumbling, rattling.
Felt by: One, several, many.
Name of observer: ....
Address of observer: ....

[On back of card.]

EARTHQUAKE INTENSITIES. (Adapted Rossi-Forel.)

1. Felt only by an experienced observer, very faint.	6. Bells rung, pendulum clocks stopped. Alarm.
2. Felt by a few persons at rest, faint.	7. Fall of plaster, slight damage. Scare.
3. Direction or duration appreciable, weak.	8. Fall of chimneys, walls cracked. Fright.
4. Felt by persons walking. Doors, etc., moved.	9. Some houses partly or wholly wrecked. Terror.
5. Felt by nearly everyone. Furniture moved.	10. Buildings ruined, ground cracked. Panic.

Avoiding seismic breaks, however, is not the only method of minimizing earthquake dangers and disasters. The injury to buildings, and through this injury the danger to life, depends not alone upon the severity of the shock but also upon the buildings themselves, their size, height, material, struts, relation of one portion to another, and all else that determines both strength and stability under the stress of an earthquake's peculiar motions.

Investigations of structural stability under earthquake shocks clearly are of the greatest practical importance to many parts of the world, including some of the best portions of our own country. But such studies presuppose a full knowledge of exactly what occurs when the crust is shaken by an earthquake. In short to determine how a building must be constructed best to resist a shake, the nature of the shake itself must first be known. Many and detailed instrumental analyses of earthquake shocks must be obtained and studied if we would seriously undertake to solve the structural problems every disastrous earthquake forces upon our attention.

The location of weak geologic faults and the design of more or less shock proof structures are two of the eminently practical applications of seismology. But neither can progress far or safely without the guidance of physical laws and the check of mathematical equations, for here, as in all other cases, use of knowledge awaits its possession; art follows science; sound theory determines safe practice.

Table 1, containing noninstrumental reports of earthquakes for December, 1914, presumably needs no detailed explanation.

Table 2, giving instrumental data obtained by the Marvin seismograph at Washington, D. C., from October 12, when instrument was restored to operation, to December 31, 1914, follows the international usage, according to which symbols have the following meaning:

CHARACTER OF THE EARTHQUAKE.

I=noticeable. II=conspicuous. III=strong.
d=(terrae motus domesticus)=local earthquake (sensible or felt).
v=(terrae motus vicinus) =near earthquake (under 1,000 km.).
r=(terrae motus remotus) =distant earthquake (1,000 to 5,000 km.).
u=(terrae motus ultimus) =very distant earthquake (over 5,000 km.).

EXAMPLES.—I_d indicates a local earthquake of small intensity but nevertheless sensible to individuals. III_r indicates a distant earthquake, the record of which shows motions of considerable amplitude.

PHASES.

P =(undae primae)=first preliminary tremors.
PRn=P waves reflected n times at the earth's surface.
S =(undae secondae)=second preliminary tremors.
SRn=S waves reflected n times at the earth's surface.
PS =transformed waves; longitudinal (P) to transversal (S), or vice versa.
L =(undae longae)=long waves in principal portion.
M =(undae maximae)=greatest motion in principal portion.
C =(coda)=trailers.
F =(finis)=end of sensible disturbance.
i =(impetus)=beginning.

NATURE OF THE MOTION.

e =(emersio)=appearance.
T=period=twice time of oscillation.
T=period of instrument.
A=amplitude of earth movement, reckoned from zero line.
E or N attached to a symbol signify E-N or N-S component respectively, thus:
A_E E-W component of A, A_N N-S component of A } measured in microns (μ), $\frac{1}{1000}$ millimeter.
V=magnification of instrument.
ε =damping coefficient.

SEISMOLOGICAL REPORTS FOR OCTOBER, NOVEMBER AND DECEMBER, 1914.

TABLE 1.—*Noninstrumental earthquake reports, December, 1914.*

Day.	Approximate time. Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
	h. m.	CALIFORNIA.	° ′	° ′			*m. s.*			
10	8 1	Eureka	40 48	124 11	2	1	5		Shook wooden buildings.	U. S. Weather Bureau.
28	10 43	Arbolado	36 15	121 47	2	1	Few.			Forest Service.
	10 43	Campbell	37 17	121 57	2	1	2			F. M. Righter.
	10 43	Coyote	37 14	121 41	4	3	4	Rumbling	Shook buildings	Stanley Sharp.
	10 43	Gilroy	37 08	121 28	2	1	25			Agent, S. P. Co.
	10 43	Oakland	37 47	122 15	2-3	1	½			C. Burckhalter.
	10 43	San Francisco	37 48	122 26	3	1	5			U. S. Weather Bureau.
	10 43	....do	37 47	122 25	3	2	2			Dominican Sisters.
	10 43	Santa Cruz	36 57	122 02	5	1	3		Shook buildings	W. R. Springer.
	10 43	Watsonville	36 55	121 46	4	2	20	Rumbling		Spreckels Sugar Co.
28	8 6	Cahuilla	33 32	116 43	2	1	1	....do		Dr. W. L. Shawk.
29	10 00	Aguanga	33 26	116 51	5	2				Forest Service.
	10 00	....do	33 26	116 51		2	2			Paul Thomsen.
	10 00	Mesa Grande	33 11	116 42	3	1	14	Rumbling		E. H. Davis.
	10 00	La Jolla	32 51	117 16	2	1	8	....do		Ben Amigo.
29	12 00	Aguanga	33 26	116 51	2	1				Forest Service.
	12 00	La Jolla	32 51	117 16	2	1				Ben Amigo.
		SOUTH CAROLINA.								
23	11 55	Summerville	33 05	80 14	1	1				Miss E. H. Gadsden.
		TEXAS.								
30	1 00	Anderson	30 31	95 55	5	1	Few.	Rumbling	(Explosion?)	Dr. Oscar Davis.
		UTAH.								
14	5 30	Enterprise	37 35	113 50	5	1	30	Rumbling		Jas. E. Hall.
21	5 25	Hurricane	37 15	113 25	2	1				Amos Workman.
21	5 25	Pine Valley	37 24	113 30	3	1	15	Faint		I. M. Gardner.
21	5 25	Pinto	37 33	113 31	2-3	1	10	Rumbling		J. H. Harrison.

TABLE 2.—*Instrumental report October, November, and December, 1914.*

[Washington, D. C. Latitude 38° 54′; longitude, 77° 03′; elevation, 21 m. Time: Mean Greenwich, midnight to midnight. Nomenclature: International. Instrument: Marvin (vertical pendulum). From Oct. 12 to Dec. 31, 1914.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1914.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 22	I_r	eP_N	6 59 54	5		2	1,400	Phase not well marked.
		S_N	7 02 21	10		6		
		L_N	7 03 05	8		4		
		F	7 11 30					
23	II_u	eP_N	6 38 09	5		16	5,920	Some doubt about phase.
		iN	6 41 21					
		S_N?	6 45 41					
		L_N	6 57 50	20				
		L_N	7 07 45	40				
		L_N	7 21 30	40				
		L	7 28 25	25		7		
		L	7 41 00					
		F	8 04 00					
Nov. 9	I?	L	1 28 40					
10	II_d	eP_N	11 24 22	4			600	
		S	11 25 28	4				
		L	11 25 50					
		M_N	11 26 [illegible]	7		18		
		F	11 37 00					
18	II_r	P_N	9 45 27	2½		1	4,175	P not on E-W.
		iS_E	9 51 24	8		10		S not on N-S except as trace.
		L_E	9 54 13	20				
		M_E	9 56 10	10		13		
		F	10 28 00					

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1914.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 24	III_r	P_N	12 12 17	3			3,640	
		S_N	12 17 43	8				
		M	12 17 56	8	82	84		
		iSR_2	12 20 59	8				
		M	12 21 07		110	136		
		F	14 04 00					
Dec. 4	I_v	eP_N?	22 46 46				770?	Phases not distinct.
		S	22 48 10	6				
		L	22 51 00	10				
		F	22 52 00					
20	II_u	P	14 27 20	3			8,000	Phases not distinct.
		PR_E	14 34 17					
		PR_N	14 34 17					
		S_E	14 36 40	8				
		S_N	14 36 40					
		L_N	14 52 45	45				
		F	16 00 00					
25	II_r	eP_N	3 46 27	2			2,160	
		iS_E	3 50 04					
		L_E	3 52 44	13				
		M_N	3 56 40			14		
		F	4 15 00					